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Memoirs of the Department of Agriculture in India

THE YIELD AND COMPOSITION OF THE MILK OF THE MONTGOMERY HERD AT PUSA AND ERRORS IN MILK TESTS

BY

J. WALTER LEATHER, V.D., Ph.D., F.I.C.

Imperial Agricultural Chemist

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Assistant to the Agricultural Adviser to the Government of India



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P R E F A C E

As DR. LEATHER has kindly insisted on my name appearing on the cover of this Memoir, I feel bound to explain that my share in its production was limited to arrangements at the dairy for a portion of the tests and to arm-chair criticism from the farmer's point of view.

The whole of the work, involving a very large number of mathematical calculations, was done by Dr. Leather, and cannot have been in any way facilitated by my collaboration.

A. C. DOBBS.

THE YIELD AND COMPOSITION OF THE MILK OF THE MONTGOMERY HERD AT PUSA, AND ERRORS IN MILK TESTS

BY

J. WALTER LEATHER, V.D., Ph.D., F.I.C.,

AND

A. C. DOBBS.

IN 1911 it was decided to make some careful tests of the yield and composition of the milk of the Montgomery or Saniwahl cattle, which is the breed maintained at Pusa. Ordinarily in India the recorded yield is that which is obtained in the usual course of milking when the calf takes at the same time an unknown quantity of milk; such records are necessarily inaccurate. Again the records of the composition of the milk that had been kept at Pusa, had been made by the dairyman and their accuracy was open to suspicion. It was decided therefore to endeavour either to avoid these and other sources of error or at least to measure their magnitude.

The tests were conducted over a period of several weeks in each case, which is longer than in most other recorded experiments.

It will be convenient firstly to consider the sources of error and subsequently to consider the data obtained.

SOURCES OF ERROR.

(i) *Period of time between milkings.*—It is well established that the periods of time which elapse between any two milkings will affect the yield and composition of the milk. If the cow is milked twice in the 24 hours and, for example, the day period is shorter than the night period, the yield will be smaller and the

percentage of fat greater at the evening milking than if the periods were equal. This source of error must either be avoided or allowed for. For the purposes of the Pusa tests it was avoided by making the milking periods equal; the variation of time from an exact 12-hour period has not been more than 5 minutes, which is a negligible quantity.

(ii) *The calf sucks at the same time as the cow is hand-milked.*—

It has been recognised that the fact of the calf sucking at the same time as the cow is hand-milked introduces an error, but so far as we are aware no attempt has been made either to negative this error or to ascertain its value. For the tests at Poona¹ “the calf was allowed to take as little milk as possible” which leaves the magnitude of the error as uncertain as though no attempt were made to avoid it.

Attempts have been made by European dairymen in India to train cows to allow themselves to be hand-milked in the absence of the calf. Colonel Hallows, Director of Military Farms and Mr. Smith, Assistant Director of Dairy Farms, inform us that in some of the Military Dairies considerable success in this matter has been achieved with half-bred Ayrshire-Indian and with Sind cattle, but that with other breeds the difficulty has not been overcome. Buffaloes frequently present less difficulty. Attempts to overcome the difficulty with the Montgomery cows at Pusa failed. Under the circumstances it seemed to us better to try to obtain accurate data with as little disturbance of this Indian custom as possible. If for example the one side of the udder were hand-milked whilst the calf sucked the other as is the practice at Pusa, it was reasonable to hope that either exactly one-half of the milk would be obtained by hand, and that half of average quality, or that at least such a method would admit of the error being estimated. In point of fact this method has proved quite successful; as will be seen, one-half of the milk is actually obtained under such conditions, and the error due to the calf sucking has been negated

¹ See Meggitt & Mann, *Memoirs Dept. of Agri., India*, Chem. Ser. Vol. II, No. 1.

during the trials, excepting one month (October) when an attempt was made to estimate its magnitude.

(iii) *Analytical errors.*—The magnitude of these is well-known to be much smaller than that due to other causes. The fat percentage was determined by Gerber's method. A series of 16 samples was tested also by extraction with ether, using the Adams' coil, as a check on the Gerber bottles, which showed that the latter frequently gave 1% fat too low, this error being largely systematic. No correction has been made for it, since it is insignificant in comparison with other sources of error.

GENERAL PLAN OF THE TESTS.

The tests were conducted during three periods: (A) December 3rd, 1911, to January 31st, 1912; (B) March 28th to June 1st, 1912; (C) September 1st to November 9th, 1912.

The following list of the cows indicates the age of the calf in each case:—

Period.	Cow.	Date of calving.	Relative yield.
A	No. 51 Khaki	30th Sept. 1911	Reduced to $\frac{1}{10}$ yield.
	No. 88 Subhagi	24th Augt. 1911	Do.
	No. 91 Amiri	30th Octr. 1911	In full milk.
B	No. 159 Kamali	17th Mar. 1912	In full milk.
	No. 128 Nami	30th Janv. 1912	Do.
	No. 101 Radhi	16th Janv. 1912	Reduced to $\frac{1}{10}$ yield.
	No. 99 Godhi	15th Decr. 1911	Reduced to $\frac{1}{10}$ yield.
	No. 44 Moghi	11th Janv. 1912	In full milk.
	No. 67 Nathali	25th Decr. 1911	Reduced to $\frac{1}{10}$ yield.
	No. 78 Rami	6th Feby. 1912	In full milk.
	No. 95 Janki	12th Janv. 1912	Do.
	No. 133 Kaveri	15th Janv. 1912	Reduced to $\frac{1}{10}$ yield.
	No. 85 Gilori	27th Decr. 1911	Reduced to $\frac{1}{10}$ yield.
	No. 33 Boudhi	1st Mar. 1912	Do.
	No. 30 Gujri	29th Janv. 1912	Do.
C	No. 160 Thoosri	21st Mar. 1912	Going off.
	No. 130 Tikya	5th July 1912	In full milk.
	No. 161 Mayani	13th Augt. 1912	Do.
	No. 31 Balli	25th June 1912	Reduced to $\frac{1}{10}$ yield.
	No. 97 Kesari	5th June 1912	In full milk.
	No. 36 Gongli	29th June 1912	Do.
	No. 42 Chikni	27th July 1912	Reduced to $\frac{1}{10}$ yield.
	No. 56 Padmini	2nd July 1912	In full milk.
	No. 50 Bhadki	18th June 1912	Reduced to $\frac{1}{10}$ yield.
	No. 15 Hoosni	15th June 1912	In full milk.

Hours of milking.—All the cows which were under observation at any time were milked about 5 A.M. and 5 P.M., the time interval being 12 hours with a variation of not more than 5 minutes.

Period A.—The cows were milked thus :—From December 5th to 22nd one-half of the udder was milked by hand, the other half being sucked by the calf. Commencing, say, with the right side (hand-milked) on December 4th morning and evening, this was followed on December 5th by hand-milking the left side morning and evening. On December 6th the right side was hand-milked morning and evening, and this sequence was followed until December 22nd. Thus during this half period the first milking by hand on either side of the udder was in the morning. Then during the 2nd half period from January 3rd to 31st the system of milking was the same, *excepting* that the first milking by hand from either side was in the evening; thus, say, on January 3rd evening, the left side was hand-milked followed again on January 4th morning by hand-milking the left side; January 4th evening the right side was hand-milked and again this same side was hand-milked on January 5th morning. Thus during the second half period the first milking by hand on either side of the udder was in the evening. The reason for making the change of side at the morning milking in December and at the evening milking in January was to distinguish between possible errors due on the one hand to the calf leaving milk in its half udder, or to the milkman imperfectly milking his side, and on the other hand to a difference in the rate of milk secretion by day and night respectively. This matter is referred to again subsequently.

Further, during this period the milk of the fore-quarter of the udder was drawn (by hand) separately from that of the rear quarter. By this system of separation some very interesting data were obtained. There was moreover with the three cows which were being tested no sign that this mode of milking caused any unknown errors. Nevertheless, partly because of the risk that such might occur, and partly because a knowledge of the quantity and quality

of the milk from the several quarters of the udder was distinct from the principal objects which we had in view, this mode of milking was not repeated in the subsequent periods B and C.

Period B.—Twelve other cows were tested. The system of milking was the same as during Period A, *excepting* that the milk of the two quarters of the udder on the one side or the other was hand-drawn together, which made the system of milking more normal. During April the first hand-milking from either side was in the morning, the second in the evening; during May the first hand-milking was in the evening and the second in the morning from that side.

Period C.—The object of Period C was to ascertain what errors were involved by hand-milking in the ordinary way when the cows are milked for profit and when as much is obtained as possible without starving the calf. Ten cows, all again different from those of Periods A and B, were brought under observation. The period was divided into three parts: C₁ September 1st to 28th, C₂ September 29th to October 26th, C₃ October 28th to November 9th.

During sub-period C₁, the cows were milked as during Periods A and B, *i.e.*, they were hand-milked from one side of the udder, the calf taking the milk of the other half; the change of side was made in the morning. During sub-period C₂ the cows were milked as for profit, no differentiation being made as to the side of the udder in respect either of hand-milking or of what the calf sucked. During sub-period C₃ the cows were milked as during sub-period C₁.

DATA OBTAINED.

In considering the data which have been obtained, it will be most convenient if they are sub-divided as follows:—

Yield of milk.

- Mean yield of milk morning and evening respectively.
- Mean yield of milk from each half udder.
- Error of the mean.
- Error of the individual milking.
- The total production of milk of each cow.

Composition of milk.

- Mean % fat in milk.
- Error of the mean.
- Error of the individual milking.
- Difference of % fat from different sides of the udder.
- Difference of % fat from different quarters of the udder.
- Difference of % fat in morning and evening milk.
- Errors involved when milking in the ordinary way.
- Effect of meteorological conditions.
- "Complete" analyses of milk of Montgomery cows.

YIELD OF MILK.

Sources of error. The first question was whether hand-milking and the sucking of the calf were equally efficient in draining the udder. If not, the amount obtained by hand-milking and weighed, would vary systematically according as a hand-milking followed the calf or a previous hand-milking. Such a variation might be obscured by any variation in the amount of milk secreted by day and by night respectively. But by shifting the change from sucking to hand-milking from night time to day time as was done,

any systematic difference due to these two causes that were additive in the first half period would tend to cancel one another in the second and *vice versa*, and we should get at least during one half period a considerable difference between the amount of the morning and evening milk. But there were no such considerable systematic differences, and in fact the amounts of milk obtained from the same side of the udder in the morning and evening during each period were remarkably similar—showing that neither the method of drawing the milk nor the period—whether of day or night—after which it was drawn, affected the amount significantly in the case of any of the cows tested.

If to these conclusions is added the fact that most of the differences between successive milkings were quite small, it becomes evident that the conclusion, that the mean yields shown in Statement II are not materially affected by these sources of error, is perfectly justified. It is the first occasion that an attempt has been made to exclude or estimate the effect of the calf-sucking at the same time as a cow is hand-milked during dairy trials in India. The result is that (i) under the conditions we have employed, just one-half the milk was obtained by hand whilst the calf took the other half, and (ii) it becomes possible to detect from our records any systematic differences in the yield of milk from the several parts of the udder.

Quantity of milk morning and evening.—In Statement I are set out the average yields of milk obtained morning and evening from each cow. Each datum is the mean of two half periods and any error due to the fact of the morning or evening milking succeeding a hand-milking or calf-sucking is more perfectly obliterated than would be the case if the averages for each month were separately set out. Thus the morning average for cow Khaki 3.50 lbs. is the mean of 3.69 lbs. in December and 3.30 lbs. in January. During December the morning hand-milking followed the calf sucking, whilst during January it followed the hand-milking of the previous evening.

Statement I.—Showing AVERAGE YIELDS (lbs.) of milk MORNING and EVENING obtained from half adder by hand.

Period	Cow	Month	Morning.	Evening.
A	Khola	December & January	3.50	3.63
	Sabbang	Do.	3.02	3.03
	Anant	Do.	3.35	3.21
B	Kamali	April & May	2.66	2.61
	Namir	Do.	2.40	2.58
	Badha	Do.	2.55	2.53
	Gadha	Do.	2.60	3.02
	Mogha	Do.	2.67	2.68
	Nathali	Do.	2.46	3.00
	Rami	Do.	3.21	3.27
	Janki	Do.	2.50	2.67
	Kayari	Do.	2.83	2.98
	Gilon	Do.	2.57	2.68
	Bondla	Do.	3.23	3.32
	Gauri	Do.	2.60	2.63
C	Phosari	September & November	4.62	4.37
	Tikva	Do.	2.01	1.98
	Meyani	Do.	2.69	2.63
	Bali	Do.	2.74	2.76
	Kesari	Do.	2.81	2.85
	Gangah	Do.	3.02	3.05
	Chikae	Do.	3.39	3.35
	Padmaja	Do.	3.84	3.81
	Bhadki	Do.	4.66	4.64
	Bhoseri	Do.	3.29	3.44

An examination of these data shows that there was no systematic difference: in fact, the yields have been in this respect very equal.

In this connection Crowther* quotes records obtained at Garforth in Yorkshire and at Offerton in Northumberland in which cows yielded very much more milk during the night time. These tests were not made at 12-hour intervals as were the Pusa tests, but even allowing for difference of system in milking, there seems little doubt that whilst some herds under one set of conditions may yield equal quantities of milk during the day and night respectively, other herds may not do so.

Quantity of milk from the two sides of the adder. In Statement II a comparison is drawn between the yields of milk from the two

* C. Crowther, *Jour. Agr. Sci.*, I, 154

Statement II. —Showing **AVERAGE YIELDS** (lbs.) per 24 hours † of milk from the **LEFT** and **RIGHT SIDE** of the udder of each cow.

	Cow.	Month.	Period, days.	Left side.		Right side.		Total, lbs.	Weighted mean production, lbs.
				lbs.	lbs.	lbs.	lbs.		
Period A.	No. 51 Khaki	Deer. Jany.	17	*7.90 ±	1.50	7.15 ±	2.80	15.05	14.05
			29	*7.17 ±	0.63	6.29 ±	0.73	13.46	
	No. 88 Subhaga	Deer. Jany.	17	6.01 ±	0.91	*7.11 ±	0.42	13.12	11.88
			29	5.08 ±	0.63	*6.07 ±	0.64	11.15	
	No. 91 Amiri	Deer. Jany.	17	7.14 ±	1.95	7.09 ±	1.81	14.23	12.88
			29	6.07 ±	1.00	6.02 ±	0.60	12.09	
Period B.	No. 159 Kamali	Apr. May	30	4.53 ±	0.48	*5.45 ±	1.15	9.98	10.55
			31	5.05 ±	0.57	*6.07 ±	0.76	11.12	
	No. 128 Nami	April May	30	4.98 ±	0.63	4.83 ±	0.85	9.81	9.96
			31	5.17 ±	0.63	4.95 ±	0.65	10.12	
	No. 101 Radhi	April May	30	4.87 ±	0.84	4.60 ±	0.56	9.47	10.16
			31	5.50 ±	0.98	5.35 ±	1.28	10.85	
	No. 99 Godhi	April May	30	5.90 ±	0.89	5.66 ±	0.99	11.56	11.85
			31	6.12 ±	0.69	6.02 ±	0.94	12.14	
	No. 44 Moghu	April May	30	4.07 ±	0.76	*6.45 ±	0.66	10.52	10.72
			31	4.62 ±	1.33	*6.30 ±	0.51	10.92	
	No. 67 Nathali	April May	30	5.90 ±	0.54	5.93 ±	0.71	11.83	12.01
			31	6.18 ±	0.66	6.02 ±	0.51	12.20	
	No. 78 Rami	April May	30	6.42 ±	0.80	6.25 ±	0.75	12.67	12.98
			31	6.60 ±	0.72	6.70 ±	0.59	13.30	
	No. 95 Janki	April May	30	4.73 ±	0.65	*5.27 ±	0.57	9.80	10.25
			31	5.20 ±	0.84	5.50 ±	0.38	10.70	
	No. 133 Kaveri	April May	30	5.93 ±	0.61	5.92 ±	1.03	11.85	11.62
			31	5.73 ±	0.65	5.65 ±	0.84	11.38	
	No. 85 Giloni	April May	30	4.85 ±	0.77	*5.20 ±	0.63	10.05	10.50
			31	5.43 ±	0.63	5.52 ±	0.59	10.95	
	No. 33 Boudhi	April May	30	6.22 ±	0.68	*7.25 ±	0.60	13.47	13.09
			31	6.10 ±	0.89	*6.62 ±	0.47	12.72	
	No. 30 Guni	April May	30						10.67
			31	4.85 ±	0.74	*5.82 ±	0.48	10.67	
Period C.	No. 160 Thoosri	Sept. Oct.-Nov.	28	3.60 ±	0.06	3.64 ±	0.06	7.24	6.42
			14	*2.68 ±	0.09	2.11 ±	0.14	4.79	
	No. 130 Tikya	Sept. Oct.-Nov.	28	4.06 ±	0.04	4.00 ±	0.02	8.06	7.98
			14	*4.11 ±	0.08	3.71 ±	0.07	7.82	

† This 24-hour period refers to the 1st and 2nd milking from the one side of the udder; it is not a calendar day.

Statement II.—continued.

	Cow.	Month.	Period days.	Left side		Right side		Total.	Weighted mean production.
				lbs.	l.	lbs.	l.		lbs.
Period C.	No. 161	Sept.	28	5.42	± .06	5.52	± .08	10.94	} 10.65
	Mayani	Oct.-Nov.	14	4.89	± .19	5.15	± .11	10.04	
	No. 31	Sept.	28	6.08	± .04	6.09	± .04	12.17	} 11.04
	Balli	Oct.-Nov.	14	4.32	± .07	4.46	± .14	8.78	
	No. 97	Sept.	28	6.21	± .05	6.09	± .07	12.30	} 11.37
	Kesari	Oct.-Nov.	14	4.75	± .07	4.75	± .06	9.50	
	No. 36	Sept.	28	6.23	± .04	6.20	± .04	12.43	} 12.20
	Gongli	Oct.-Nov.	14	5.89	± .05	5.86	± .05	11.75	
	No. 42	Sept.	28	7.67	± .07	7.61	± .06	15.28	} 13.54
	Chikni	Oct.-Nov.	14	4.82	± .11	*5.25	± .15	10.07	
	No. 56	Sept.	28	8.27	± .07	8.36	± .08	16.63	} 15.27
	Padmini	Oct.-Nov.	14	6.11	± .07	6.43	± .08	12.54	
	No. 50	Sept.	28	9.90	± .08	9.84	± .08	19.74	} 18.64
	Bhadki	Oct.-Nov.	14	8.32	± .07	8.11	± .12	16.43	
	No. 15	Sept.	28	11.73	± .16	11.80	± .15	23.53	} 21.53
	Hoosni	Oct.-Nov.	14	8.82	± .12	8.71	± .25	17.53	

halves of the udder, namely, the left and right sides. A careful scrutiny of the data shows that in certain cases the yield was greater by more than .3 lb. on the one side than on the other; such instances are marked *; smaller differences are considered accidental.

Thus cow Khaki yielded .75 lb. in December and .88 lb. milk in January more from the left half udder than from the right. Cow Subhagi yielded 1.1 lb. in December and .99 lb. in January more from the right than from the left half udder. Altogether there are five such cases among the 25 cows. In addition, there are six other instances in which a cow yielded more milk from one side than from the other during one month, whilst no significant difference occurred in the other month. These latter are not systematic and must be considered accidental. Moreover, five of them are small differences; in any case their cause is not known. Of the five which are apparently systematic, four are instances of a higher

yield from the right half udder. It is of course possible that such differences are characteristic of certain cows, but they are more probably due to the local loss of function that is so common in the cow's udder and is caused by mechanical injury or sporadic inflammation. It is however clear that such differences do not occur among the majority of cows, at least in this herd. The quantities are usually equal from each side of the udder.

The error of the mean.—The probable error of the mean yield is shown under r_2 , in Statement II, and is in most cases less than ± 1 . The arithmetical mean of these values is ± 0.8 . The conclusion may therefore be drawn that there is a probability of about 100 : 1 that these means are within .3 lb. of the truth.

The error of the individual milking.—The error which occurs among individual milkings is considerable. During Period A the probable error was ± 2.9 , for Period B, ± 2.8 , for Period C, ± 2.6 . It serves to show how necessary it is in milking trials to conduct the test over a fairly long period if reasonable accuracy is to be attained. If dependence were placed on an individual milking, the yield might readily be 1 lb. or more wrong.

The daily production of each cow.—The total amount of milk of each cow per day is set out in the last column of Statement II and is obtained from the sum of the yield of the left and right half udders. It has been already explained why this summation is dependable, and it is only here necessary to remind the reader that this is the total production, and not the amount actually obtainable under Indian conditions. The latter is discussed subsequently. A consideration of these quantities shows that during Periods A and B the differences between the daily production for the two half-periods respectively, that is the differences between the quantities for December and for January, and between those for April and May respectively in any one case, varied from about .5 lb. up to 2.0 lbs.; those for Period C are greater in some cases, the variation then being from less than .5 lb. up to as much as 5 lbs. These will be referred to later. The last column of Statement II

contains the mean production for each cow, from which it is seen that the quantity for the period of these tests varied from 6.4 lbs. to 21.5 lbs.

COMPOSITION OF THE MILK.

The % fat was determined in samples of the milk daily; in addition more complete analyses were made in some samples which are referred to subsequently.

Statement III. Showing mean percentage of FAT in cows' milk for the LEFT and RIGHT HALVES of udder, MORNING and EVENING respectively, and the value of the probable error r_e of each.

Cow.	Month.	Period days.	LEFT SIDE		RIGHT SIDE		Weighted mean % Fat.
			Morning.	Evening	Morning.	Evening.	
			Fat % r_e	Fat % r_e	Fat % r_e	Fat % r_e	
Khaki	Deer.	17	4.85 ± .11	3.98 ± .07	4.85 ± .14	3.98 ± .09	4.33
	Jan'y.	29	4.63 ± .07	4.12 ± .05	4.62 ± .03	3.74 ± .05	
Subhagi	Deer.	17	4.82 ± .07	3.75 ± .05	4.90 ± .17	4.30 ± .20	4.46
	Jan'y.	29	4.96 ± .08	4.00 ± .08	4.79 ± .10	4.10 ± .08	
Annu	Deer.	17	4.56 ± .04	3.84 ± .07	4.55 ± .04	3.95 ± .11	4.24
	Jan'y.	29	4.77 ± .03	3.95 ± .05	4.46 ± .06	3.80 ± .04	
Kamali	April	30	4.69 ± .10	3.50 ± .09	4.91 ± .07	3.43 ± .08	4.21
	May	31	4.73 ± .06	3.52 ± .07	3.30 ± .06	3.62 ± .07	
Nata	April	30	5.13 ± .09	4.28 ± .06	5.08 ± .12	4.55 ± .06	4.88
	May	31	5.33 ± .05	4.63 ± .06	5.44 ± .07	4.57 ± .03	
Rachha	April	30	4.64 ± .11	3.46 ± .06	4.90 ± .12	3.83 ± .07	4.13
	May	31	4.82 ± .07	3.96 ± .06	5.02 ± .16	4.04 ± .07	
Godhi	April	30	4.20 ± .05	3.00 ± .03	4.01 ± .09	2.87 ± .05	3.53
	May	31	4.11 ± .06	3.04 ± .04	4.22 ± .08	2.96 ± .04	
Mochi	April	30	4.75 ± .13	3.66 ± .12	5.48 ± .26	3.73 ± .10	4.43
	May	31	4.94 ± .12	3.72 ± .09	5.36 ± .16	3.83 ± .11	
Nathali	April	30	5.33 ± .14	4.93 ± .15	5.64 ± .23	4.75 ± .17	5.23
	May	31	5.64 ± .12	4.94 ± .12	5.80 ± .15	4.93 ± .10	
Rani	April	30	4.08 ± .05	3.7 ± .08	3.98 ± .09	3.69 ± .05	4.12
	May	31	4.89 ± .08	4.18 ± .06	4.73 ± .10	3.81 ± .09	
Lanka	April	30	5.25 ± .15	3.54 ± .06	5.40 ± .17	3.67 ± .04	4.48
	May	31	5.01 ± .09	3.78 ± .05	5.38 ± .11	3.85 ± .07	

Statement III.—continued.

Cow.	Month.	Period days.	LEFT SIDE.		RIGHT SIDE.		Weighted mean o o Fat.
			Morning.	Evening.	Morning.	Evening.	
			Fat ^o _o r_2	Fat ^o _o r_2	Fat ^o _o r_2	Fat ^o _o r_2	
Kaveri {	April	30	3.96 ± .09	2.93 ± .03	3.74 ± .09	2.97 ± .06	3.42
		31	3.91 ± .04	2.92 ± .04	4.06 ± .05	2.89 ± .02	
Gileri {	April	30	4.18 ± .09	2.75 ± .06	4.10 ± .10	2.85 ± .04	3.54
		31	4.33 ± .06	2.96 ± .04	4.31 ± .06	2.90 ± .04	
Boudhi {	April	30	4.10 ± .12	3.21 ± .06	4.36 ± .10	3.58 ± .09	3.87
		31	4.46 ± .09	3.16 ± .06	4.60 ± .10	3.50 ± .07	
Gupi {	April	30					4.76
		31	5.20 ± .16	3.89 ± .06	5.68 ± .14	4.28 ± .06	
No. 160 { Thoosri {	Sept.	28	5.37 ± .17	4.40 ± .15	5.23 ± .09	4.10 ± .09	4.83
		14	5.42 ± .11	4.55 ± .19	5.15 ± .17	4.68 ± .16	
No. 130 { Tikya {	Sept.	28	4.85 ± .09	4.10 ± .06	4.91 ± .09	4.15 ± .07	4.72
		14	5.38 ± .10	4.72 ± .15	5.43 ± .13	5.12 ± .09	
No. 161 { Mayani {	Sept.	28	3.88 ± .06	3.26 ± .08	3.98 ± .07	3.33 ± .06	4.17
		14	5.12 ± .18	5.07 ± .21	5.88 ± .21	5.10 ± .12	
No. 31 { Balli {	Sept.	28	4.90 ± .11	3.66 ± .06	4.77 ± .11	3.82 ± .06	4.48
		14	5.60 ± .14	4.07 ± .16	5.51 ± .13	4.37 ± .13	
No. 97 { Kesari {	Sept.	28	3.90 ± .15	3.21 ± .10	4.04 ± .15	3.32 ± .07	4.03
		14	4.83 ± .17	4.95 ± .16	5.12 ± .20	4.62 ± .07	
No. 36 { Gongli {	Sept.	28	4.20 ± .10	3.36 ± .10	4.19 ± .10	3.44 ± .10	4.05
		14	4.52 ± .10	4.40 ± .10	4.90 ± .16	4.43 ± .05	
No. 42 { Chikni {	Sept.	28	4.16 ± .08	3.30 ± .05	4.59 ± .13	3.45 ± .10	4.00
		14	4.87 ± .20	3.57 ± .10	4.70 ± .17	3.88 ± .10	
No. 56 { Padmini {	Sept.	28	4.88 ± .08	4.12 ± .05	4.84 ± .07	4.06 ± .07	4.89
		14	6.03 ± .15	5.37 ± .17	5.82 ± .17	5.53 ± .19	
No. 50 { Bhadki {	Sept.	28	3.41 ± .06	3.05 ± .04	3.48 ± .08	2.90 ± .06	3.45
		14	4.03 ± .17	3.93 ± .26	4.23 ± .18	3.65 ± .14	
No. 15 { Hoosni {	Sept.	28	3.58 ± .06	3.09 ± .11	3.70 ± .10	3.20 ± .10	3.51
		14	3.72 ± .10	3.68 ± .12	4.15 ± .23	3.53 ± .16	

Mean % fat.—The per cent. fat was determined by the Gerber method, which, as has already been mentioned, was apparently

subject to a systematic error of about 1%. No correction was made for this because the other errors are probably greater. In Statement III are set out the mean % fat for each cow, during each sub-period, for the milk of the left and right hand sides of the udder and for morning and evening respectively, from which it is seen that the milk of this herd contains generally from 4 to 6% of fat. This statement likewise sets out the value of the *probable error of the mean*, r_0 . The errors of the mean percentage as shown in Statement III are commonly about ± 1 which gives a high probability that the mean per cent. fat is not wrong by .3. Differences greater than this amount may therefore be considered significant.

The error of the individual milking.—The values of the probable error for individual milkings were found to be .22 for Period A, $\pm .31$ for Period B, and $\pm .33$ for Period C. This means that there is a probability of about 1 in 24 that the % fat of any individual milking will be $\pm .9$ in error. There is perhaps nothing very novel in this fact, for it is generally recognised that isolated tests of individual cow's milk are "doubtfully correct," but it is difficult to find data on the subject in the literature.

The mean percentage of fat in the milk for all the cows, after weighting for differences of period, is 4.23 which is the best value that is obtainable for the herd at Pusa.

Difference in % fat from different sides of the udder.—From the data contained in Statement III the percentage of fat in the milk from the left and right sides of the udder respectively may be compared. This comparison is simplified by taking the means of morning and evening in each case, as exhibited in Statement IV. Thus 4.41% (Statement IV) is the mean of 4.85 and 3.98, cow Khaki, December, left side (Statement III). In the last column of Statement IV are set out the differences between the % fat of left and right sides respectively, and these differences place it beyond doubt that they must be considered purely accidental. There are

Statement IV.—Showing mean percentage of FAT in milk from LEFT and RIGHT SIDE of udder respectively.

Cow.	Month.	Left side Fat %	Right side Fat %	Left side + or — right side.
Khaki ..	December ..	4.41	4.41	— 0
	January ..	4.37	4.18	+ .19
Subhagi ..	December ..	4.27	4.60	— .33
	January ..	4.48	4.44	+ .04
Amiri ..	December ..	4.20	4.25	— .05
	January ..	4.36	4.13	+ .23
Kamali ..	April ..	4.09	4.17	— .08
	May ..	4.12	4.46	— .34
Nami ..	April ..	4.70	4.76	— .06
	May ..	5.08	5.00	+ .08
Radhi ..	April ..	4.05	4.36	— .31
	May ..	4.38	4.53	— .15
Godhi ..	April ..	3.60	3.44	+ .16
	May ..	3.57	3.56	+ .01
Moghi ..	April ..	4.20	4.60	— .40
	May ..	4.33	4.60	— .27
Nathali ..	April ..	5.13	5.17	— .04
	May ..	5.29	5.36	— .07
Rami ..	April ..	3.91	3.83	+ .08
	May ..	4.49	4.27	+ .22
Janki ..	April ..	4.38	4.53	— .15
	May ..	4.39	4.61	— .22
Kaveri ..	April ..	3.44	3.35	+ .09
	May ..	3.41	3.47	— .06
Giloni ..	April ..	3.46	3.47	— .01
	May ..	3.64	3.60	+ .04
Boudhi ..	April ..	3.65	3.97	— .32
	May ..	3.81	4.05	— .24
Gujri ..	April ..	4.54	4.98	— .44
No. 160 Thoosri ..	September ..	4.88	4.66	+ .28
	November ..	4.98	4.91	— .07
No. 130 Tikya ..	September ..	4.47	4.53	— .06
	November ..	5.05	5.29	— .24
No. 161 Mayani ..	September ..	3.57	3.65	— .08
	November ..	5.09	5.49	— .40

Statement IV.—continued.

Cow.	Month.	Left side Fat	Right side Fat	Left side — Right side.
No. 31 Balli ..	{ September ..	4.28	4.24	-.04
	{ November ..	4.83	4.94	-.11
No. 97 Kesari ..	{ September ..	3.55	3.68	-.13
	{ November ..	4.89	4.87	+.02
No. 36 Gough ..	{ September ..	3.78	3.81	-.03
	{ November ..	4.46	4.60	-.20
No. 42 Chakra ..	{ September ..	3.73	4.02	-.29
	{ November ..	4.22	4.29	.07
No. 56 Padma ..	{ September ..	4.30	4.45	-.05
	{ November ..	5.70	5.67	+.03
No. 50 Bhadli ..	{ September ..	3.25	3.19	+.04
	{ November ..	3.98	3.94	+.04
No. 15 Harsini ..	{ September ..	3.33	3.45	-.12
	{ November ..	3.70	3.84	-.14

altogether seven instances in which the difference exceeds .03, but in only one case, namely, cow "Moghi" could it be considered systematic. Taken as a whole the evidence is quite definite that there is no sign of any systematic difference in the quality of the milk of the two sides of the udder. Given a test over a sufficiently long period it would be safe (for cows of this herd) to depend on the milk of either side of the udder for a fair sample, though no doubt it is better to test the milk of both sides together.

Difference in fat in milk from different quarters of the udder.

As has been already mentioned, the milk was drawn during December and January separately from the fore and hind-quarters. Only three cows were thus tested and consequently it is hardly safe to draw conclusions very definitely from the results.

A consideration of the *differences* shown in the upper statement or of the *numbers* in the lower statement indicates that there seem to be *characteristic* differences among cows in respect of the quality

Statement V.—Comparison of FAT percentage in FORE and HIND-QUARTERS.

Cow.	Month.	Mean % Fat.		Difference.	Mean % Fat.		Difference.
		L.F.	L.H.		R.F.	R.H.	
Khaki ..	December ..	4.40	4.48	H .08	4.43	4.39	F .04
	January ..	4.33	4.36	H .03	4.23	4.01	F .22
Subhagi ..	December ..	4.30	4.35	H .05	4.69	4.51	F .18
	January ..	4.54	4.27	F .27	4.68	4.25	F .43
Amiri ..	December ..	4.16	4.30	H .14	4.20	4.33	H .13
	January ..	4.23	4.33	H .10	4.04	4.22	H .08

The number of instances when one quarter produced richer milk than another quarter.

Cow.		Khaki.		Subhagi.		Amiri.	
December ..	..	L.	R.	L.	R.	L.	R.
No. of tests ..	..	13	12	13	12	13	12
F ..	..	3	1	2	6	0	1
H ..	..	4	0	4	0	7	7
January ..	..	..	..	..	..	..	..
No. of tests ..	..	22	18	22	17	22	17
F ..	..	6	10	17	15	2	1
H ..	..	7	2	0	0	8	7

of the milk which they produce in the several quarters of the udder. Of the three cows, cow "Khaki" showed no general difference between the milk of the several quarters: cow "Subhagi" yielded milk which was very generally richer from the fore than from the hind-quarter: whilst thirdly, cow "Amiri's" milk was regularly richer from the hind-quarter than from the fore-quarter. Individual differences would not be significant unless greater than .1, because the experimental error in reading the fat percentage on the Gerber bottle is at least .05 in each of two cases. Thus in order to compare the quality of the milk of any two quarters differences greater than .1 may be employed. The numbers set out in the lower

statement show the number of occasions on which the fore or hind-quarter was the richer.

Ingle made some tests on this point at Garforth in 1902.* Samples were taken from each quarter of the udder of each of 19 cows, and it was found that the milk of the left fore-quarter of ten of these was poorer in solids-not-fat than from any of the other three quarters; in three cases it was poorer from the right hind-quarter; the other cases showed no characteristic differences. Ingle found however that a month later the left hind-quarter of one of the cows was poorest instead of the left fore-quarter. It is to be noted however that these tests included only *one* sample from each quarter, and bearing in mind the large experimental error which usually accompanies individual samples, no great weight can be attached to the record.

Difference of % fat in morning and evening milk.—In Statement VI the mean % fat in the morning and evening milk respectively for each sub-period and for each cow is set out. These percentages are derived from those in Statement III by taking the mean percentage of the left and right half-udders. Thus for cow Khaki, January, evening, 3.93 (Statement VI) is the arithmetic mean of 4.12 and 3.74 (*vide* Statement III) and for cow Subhagi, December, morning, 4.86 is the mean of 4.82 and 4.90. A cursory glance at the figures shows that the morning milk was for every cow richer than the evening, and even amongst the individual milkings it was very rare that this was not the case. In the last column of the statement the differences are set out. These vary a good deal; in some cases the difference is as small as .3%, but more generally it ranges from three-fourths to one and a half per cent. The mean difference for all the cows is .91% after weighting for differences of period. It is obviously far in excess of any experimental error.

* *Jour. Agr. Sci.*, I, 171.

Statement VI.—Showing mean percentage of FAT in MORNING and EVENING milk respectively.

Cow.	Month.	Morning Fat. %	Evening. Fat. %	Difference morning > evening.
Khaki ..	December ..	4.85	3.98	.87
	January ..	4.63	3.93	.70
Subhagi	December ..	4.86	4.02	.84
	January ..	4.87	4.05	.82
Amiri ..	December ..	4.55	3.89	.66
	January ..	4.61	3.87	.74
Kamali	April ..	4.80	3.46	1.34
	May ..	5.01	3.57	1.44
Nami ..	April ..	5.15	4.31	1.16
	May ..	5.48	4.60	.88
Radhi ..	April ..	4.77	3.64	1.13
	May ..	4.92	4.00	.92
Godhi ..	April ..	4.10	2.93	1.17
	May ..	4.16	2.97	1.19
Moghi ..	April ..	5.11	3.69	1.42
	May ..	5.15	3.77	1.38
Nathah	April ..	5.47	4.83	.64
	May ..	5.72	4.93	.79
Rami ..	April ..	4.03	3.72	.31
	May ..	4.76	3.99	.77
Janki ..	April ..	5.32	3.60	1.72
	May ..	5.19	3.81	1.38
Kaveri..	April ..	3.85	2.95	.90
	May ..	3.98	2.90	1.08
Gilori ..	April ..	4.14	2.80	1.34
	May ..	4.32	2.93	1.39
Boudhi	April ..	4.23	3.39	.84
	May ..	4.53	3.33	1.20
Gujri ..	April ..			
	May ..	5.44	4.08	1.36
No. 160 Thoosri ..	September ..	5.30	4.25	1.05
	October ..	5.54	4.49	1.05
	November ..	5.28	4.61	.67
No. 130 Tikya ..	September ..	4.88	4.12	.76
	October ..	5.89	5.06	.83
	November ..	5.40	4.92	.48
No. 161 Mayani ..	September ..	3.93	3.29	.64
	October ..	4.73	4.30	.43
	November ..	5.50	5.08	.42

Statement VI.—continued.

Cow.	Month	Morning Fat.	Evening Fat.	Difference morning—evening
No. 31 B. H.	September	4.83	3.74	1.09
	October	5.76	3.99	1.77
	November	5.55	4.22	1.33
No. 97 K. S. S.	September	3.97	3.26	.71
	October	5.22	4.23	.99
	November	4.97	4.78	.19
No. 36 G. S. S.	September	4.29	3.40	.89
	October	5.21	4.42	.82
	November	4.71	4.41	.30
No. 42 Ch. S. S.	September	4.37	3.37	1.00
	October	5.16	3.81	1.35
	November	4.78	3.72	1.06
No. 56 Padma.	September	4.86	4.09	.77
	October	5.74	5.21	.53
	November	5.92	5.45	.47
No. 59 Bh. S. S.	September	3.44	2.97	.47
	October	4.37	3.74	.63
	November	4.13	3.79	.34
No. 15 H. S. S.	September	3.64	3.14	.50
	October	4.30	3.45	.85
	November	3.93	3.60	.33

In England the difference in per cent. fat in morning and evening milk, when the periods between milkings are equal, is commonly a small one in favour of the morning milk.¹ At Poona, Meggitt and Mann² found that the evening milk of Gir and Sind cows was richer than that of the morning by approximately 1.0% fat. The periods of time which intervened between milkings at Poona were not, however, equal. Dr. Mann informs us that the cows were milked between 2 and 4 A.M. and between 12 noon and 2 P.M.; thus the periods may have been anything between 12 hours; 12 hours and 8 hours; 16 hours. The latter difference of period would account for a difference of 1.8% fat in favour of the evening milk, whilst if most of the periods were midway between the extremes, it would account for a difference of .8% fat. Messrs.

¹ S. D. C. 1907, p. 17. ² S. D. C. 1907, p. 17. ³ S. D. C. 1907, p. 17.

Meggitt and Mann appear to have overlooked this influence in the % fat, and it remains an open question whether the Gir and Sind cows would not have yielded milk actually richer in the *morning* than in the evening if the periods between milkings had been equal.

Similarly, the tests which are quoted by Crowther¹ and in which the morning milk was found to be less rich than that of the midday or evening milking, do not provide very dependable evidence. At Garforth the intervals were equal, namely, 6 hours each, but this system was novel and was continued only for four days. At Offerton the intervals were 11, 8 and 5 hours.

Ingle's figures on this point are at variance with the general experience in England, but the average yield of milk after the 6-hour interval preceding 5 A.M. was so remarkable in the tests mentioned by him (40 lbs. as compared with 24 lbs. for other 6-hour intervals at Garforth) as to warrant an inference that the conditions were abnormal. The system of milking at 6-hour intervals was indeed novel, and continued only for four days, and it is not necessary to endorse Ingle's own suggestion, that the cows had become accustomed to produce richer milk in the day time by the long period during which they had been milked at the unequal intervals, in order to account for a difference in fat content, that, as his figures for absolute yield of fat show, is more than explained by the fact that for nervous or other reasons the cows yielded an excess of 66% of milk during the six hours preceding dawn.

There is of course abundant evidence to show that when the intervals between the milkings are very unequal, the quantity of milk given is usually greater and the fat % less after the longer interval. But that this is not always the case when the intervals are considerably less than 12 hours does seem to be shown by some of the figures obtained at Offerton with respect to cows milked three times in the 24 hours.

Errors involved when milking in the ordinary way.—The chief object of the tests which were made during Period C was to ascer-

¹ *Jour. Agr. Sci.*, 1, p. 171.

tain the errors which occur when cows are milked in the ordinary way. The method of experiment has been already detailed (page 151). It will be recollected that the ten cows were first milked for four weeks in September under the same conditions as in previous tests; they were then milked for four weeks as for profit; after which they were again milked for two weeks as in September.

The yield of milk. The mean yield of milk is set out in Statement VII for each of the ten cows, together with the error, r_0 , of the mean. In Statement VIII are set out the values of the probable error r of the individual milking.

Statement VII. Showing the mean YIELDS of milk during PERIOD C.

Cow.	SEPTEMBER 28 DAYS		OCTOBER 28 DAYS		NOVEMBER 14 DAYS	
	Left side. lbs.	Right side. lbs.	Left side. lbs.	Right side. lbs.	Left side. lbs.	Right side. lbs.
No. 160 P.	4.60	.06	5.64	.06	5.34	.07
No. 166 P.	4.06	.04	4.06	.02	7.06	.09
No. 161 Mayani ..	.42	.06	6.52	.08	8.06	.06
No. 34 B.	6.08	.04	6.09	.04	9.26	.13
No. 97 K.	6.21	.06	6.09	.07	9.39	.11
No. 36 C.	6.23	.04	6.29	.04	10.72	.09
No. 42 C.	.67	.07	7.61	.06	10.64	.16
No. 36 P.	8.27	.07	8.36	.08	15.25	.18
No. 30 B.	6.36	.08	9.84	.08	6.45	.26
No. 16 H.	11.73	.16	11.86	.15	17.22	.30

Statement VIII. Showing the values of the probable error, r , for individual milkings during Period C.

Cow.	SEPTEMBER 28 DAYS		OCTOBER 28 DAYS		NOVEMBER 14 DAYS	
	Left side. r	Right side. r	Left side. r	Right side. r	Left side. r	Right side. r
No. 160 P.	.22	.23	.49	.24	.24	.37
No. 166 P.	.14	.07	.47	.21	.21	.18
No. 161 Mayani ..	.23	.23	.33	.50	.29	.29
No. 34 B.	.14	.16	.07	.19	.38	.17
No. 97 K.	.12	.28	.09	.19	.13	.17
No. 36 C.	.14	.16	.47	.15	.13	.13
No. 42 C.	.27	.23	.87	.29	.39	.39
No. 36 P.	.24	.32	.31	.19	.21	.21
No. 30 B.	.25	.31	1.05	.19	.30	.30
No. 16 H.	.56	.31	1.60	.32	.67	.67

The reliability of these tests is more perfectly judged from the values of r in Statement VIII than from those of the probable error of the mean r_0 in Statement VII, because the former is not so seriously affected by the difference of length of the periods. The values of the probable error are very similar for the sub-periods C_1 and C_2 respectively, those of C_1 being somewhat the greater. Compared with sub-period C_2 , they are for nine cows out of the ten, very much smaller, being only about one-third as great. Thus the effect of hand-milking in the ordinary way when the calf takes an indefinite amount of milk, is to yield results which are open to a very much larger experimental error than when the portion taken by the calf is controlled in the manner which was adopted during the major part of these trials.

Referring to the probable error of the mean, r_0 , of Statement VII, it must be recollected that this is, for September or November, derived from only one-half and one-quarter respectively the number of milkings on each side of the udder, as of milkings in October, which explains why the differences between the several values are not so great as those of the probable error, r , of Statement VIII.

The actual yields of milk are of less importance in this respect. They varied within much wider limits than did those of Periods A and B.

The amount of milk taken by the calf. It has been shown (p. 153) that during the periods when the one-half of the udder was sucked, the calf must have taken one-half the total milk. It is therefore possible to form an estimate of how much the calf took during October on the assumption that the production during this month was the mean of that of the preceding and succeeding months. This information is set out in the subjoined Statement IX.

Statement IX. —Showing the amount of MILK taken by the CALF.

Cow.	Weighted mean total produc- tion per day during sub- periods	Mean yield by hand per day during sub-period	Difference taken by calf daily during sub-period	Portion taken by calf daily during sub- periods
	C & C	C	C	C & C
	lbs.	lbs.	lbs.	lbs.
Theresa	6.42	5.14	1.28	3.21
Takara	7.98	7.06	.92	3.99
Maya	10.65	8.56	2.09	5.33
Balla	11.04	9.26	1.78	5.52
Kesari	11.37	9.39	1.98	5.68
Gough	12.20	10.72	1.48	6.10
Chidari	13.54	10.54	3.00	6.77
Padma	15.27	13.25	2.02	7.63
Bhadra	18.64	15.45	3.19	9.32
Hosari	21.53	17.22	4.31	10.76

A consideration of the last two columns of this statement shows that the calf had about one-third as much milk during October when the cow was milked for profit, as during the other sub-periods.

Effect of meteorological conditions. It is generally considered that milch-cows are commonly affected by changes in the weather, which is reflected in either yield or quality of the milk, or both. Assuming that this is so, it *might* be a chief contributory cause of the comparatively large error which we have found in yield and quality for any one milking. In that case comparison of daily meteorological data with the milk data should show a defined correlation between cause and effect. Our tests were not designed with a view to tracing such a correlation, and hence we are not in a position to make it thoroughly. At the same time we have, as a matter of fact, compared the daily milk data with the meteorological data and have failed to trace any definite connection.

Analysis of Montgomery cattle milk.—This memoir would be incomplete if some examples of the more complete analyses of the milk of this herd were not quoted: these are set out in the accompanying Statement X.

Statement X.—Showing the composition of the milk of each cow.

	Period A.			Period B.												
	Khasi.	Sodhok.	Aburi.	Kamoli.	Namoi.	Radhi.	Gothi.	Mogla.	Nathok.	Ram.	Janki.	Kaveri.	Tobari.	Budhi.	Gojhi.	
	No. 51.	No. 88.	No. 91.	No. 159.	No. 128.	No. 101.	No. 99.	No. 34.	No. 67.	No. 78.	No. 98.	No. 133.	No. 85.	No. 33.	No. 30.	
Fat ..	1.49	1.59	1.45	8.40	7.32	1.90	3.73	1.40	3.45	1.39	1.93	4.45	3.90	1.95	1.1	
Solids-not fat	8.25	8.40	8.33	8.66	9.51	9.00	8.26	8.71	8.78	8.12	8.41	8.90	8.18	8.60	8.28	
Total solids	12.60	13.00	12.78	13.56	11.83	13.90	11.96	13.11	14.20	1.12	12.93	15.91	12.13	12.85	1.47	
Sp. gr. ..	1025	1029	1028	1029	1030	1031	1029	1031	1031	1029	1030	1029	1029	1028	1026	

Period C.

	Thosari.	Tilwa. Mayari.		Balhi.	Kesari.	Gough.	Chakra.	Pahoma.	Bhewari.	Hosari.
	No. 100.	No. 130.	No. 141.	No. 31.	No. 37.	No. 30.	No. 12.	No. 56.	No. 50.	No. 1
Fat ..	5.12	4.26	4.17	4.90	4.40	1.02	1.39	5.21	3.53	3.39
Solids-not fat	8.80	8.87	8.90	8.71	8.50	8.22	8.1	8.35	7.95	8.21
Total solids	11.92	13.88	12.97	12.90	12.90	12.81	12.69	13.66	11.96	11.90
Sp. gr. ..	1029	1029	1028	1030	1028	1028	1028	1028	1028	1028

GENERAL CONCLUSIONS.

Although the initial object in view, when it was decided to keep a series of special records of the milk of the Montgomery herd at Pusa, was to ascertain its average yield and quality, the primary object almost immediately became a check on the *errors of experiment* which occur in obtaining such records. It has thus happened that throughout the work the mind has been concentrated on these errors rather than on the actual yield and fat percentage, although the latter were at the same time ascertained.

Of the two chief known sources of error, that due to *difference of period between milkings* can be readily extinguished by making the periods equal, and this presents no difficulties. The other, namely, the *error due to the calf sucking* while the cow is hand-milked, has been overcome by the simple arrangement of allowing it to suck the one half udder only whilst the other half is entirely hand-

milked. This procedure has presented no difficulties, and for such cows as the Montgomery breed at Pusa the data show very definitely that the calf actually took one-half of the milk. The question was naturally raised as to whether this would be so in all cases, but there is no doubt that even with those cows whose total yields were the largest (for example, cow Hoosni, 21 lbs. per day), the calf took the half during September and November.

In estimating the magnitude of the error which would occur if milk yields are estimated by simply milking as for profit when the calf takes an unknown quantity, the value of the probable error, r , shows that this is at any rate three times as great as it is if the calf is allowed the whole of the milk from one side of the udder. Thus it is evident that the procedure we have adopted reduces the error in estimating milk yields under Indian conditions very much indeed.

The probable error in the estimation of the % fat in individual samples we have found to be about ± 3 . It is of interest to compare this with such other similar data as are obtainable from published records, although the latter are not strictly comparable chiefly because the records are not for consecutive days. Those published by Meggitt and Mann¹ refer only to single samples taken once a week (on Fridays), although at first sight the figures appear as averages for the week. The probable error for some of these cows is as follows:—

Cow No.			A.M.		P.M.	
1	.	0.1	5.48	66	6.41	.72
3	.		4.29	38	4.80	.18
4	.		4.77	44	5.50	.60
5	.	1.0	4.82	23	5.80	.63

It is at once apparent how much smaller was the error at Pusa when the calf was restricted to the one half udder. The errors which accompanied the Poona tests are indeed very similar to those relating to yield which occurred at Pusa in October 1912

¹ *Memo. Dep. Agr. Ind.*, Ser. V, 11, No. 1.

when the calf took an unknown quantity of milk (*cide* Statement VIII, page 168). Some other records published by the Durham County Council¹ showed the following errors:—

				A.M.		P.M.	
Cow No. 3	..	..	3.62	32	4.08	28	
.. .. 5	..	..	3.90	54	3.93	51	
.. .. 6	..	..	4.01	37	4.72	47	

The *required number of tests* of any one cow in order to obtain a mean value of % fat within certain limits may be judged from these records. It will naturally depend on the degree of exactitude required, but it is evident that when 14 or 15 tests are made, as for example from either side of the udder during April and May, the value of r_n for % fat was in the neighbourhood of .1. This is equivalent to a probability of about 24 : 1 that the experimental error does not exceed .3% fat. If therefore such a degree of exactitude is not considered sufficient, the number of tests would have to be increased very considerably in order to reduce the error materially.

Regarding the maximum *yield* of milk of cows of this herd per day this may be said to vary for different cows, from 7 to 20 lbs. Among the greater number of the cows the variation was not nearly so great and about 12 lbs. may be said to be an average figure. It is to be recollected that this is the maximum *production*; when milking in the ordinary way for profit the calf had about 2 lbs. of this, leaving some 10 lbs. as the average maximum yield to the milkman.

Information regarding the yields of other Indian breeds is comparatively scarce. Details for Gir and Sind cows are given by Meggitt and Mann, but it is quite uncertain how much the calf took. On the days when the samples were taken, once a week the calf was allowed "as little as possible," but presumably the yields which are quoted refer to the actuals, all days included,

obtained in practical dairying. In that case the circumstances would be comparable with those of our period C, October 1912. The average yield for Gir cows per head per day was found to be about 6 lbs. and for Sind cows about 10 lbs.; if to these be added some 2-4 lbs. probably taken by the calf, the sum would indicate a total production of milk similar to that which we have found for the Montgomery breed. The estimate is obviously only a very rough one, but it is the best that one can make. In comparison with European cattle it is hardly necessary to point out that such yields fall far short of an European average. Even Jersey cattle will commonly yield a maximum of 25 lbs. and breeds like the Shorthorn 35 lbs. in the day.

In respect of richness Indian cows' milk has generally been found to contain a higher percentage of fat than that of most European cattle. Among the Montgomery cattle which were included in our tests, the % fat varied from about 3.5 to 5.0. This is less than what Meggitt and Mann found in the milk of the two breeds at Poona: the milk of the Gir cows contained from 5.0 to 6.0%, that of the Sind cows from 5.0 to 6.5%. But the fact of the calf drawing an unknown quantity of the first and poorer milk in those tests would naturally increase the % fat in the remainder.

Our mode of experiment has enabled us to draw certain conclusions regarding the *yield and quality of the milk from the several parts of the udder*. Certain of the cows appeared to yield rather more milk from one side of the udder than from the other; altogether there were five such instances among 25 cows. On the whole however the experiments have shown that that obtained from opposite sides is, as indeed would be expected, generally similar both in quantity and quality. But it is less in accordance with expectation that the milk from the fore and hind-quarters should have been found to differ very greatly, not only as is commonly observed, in quantity, but also in quality. The tests of the milk from the several quarters of the udder of three cows indicated that there are differences in quality characteristic of the cow;

one cow yielded milk from the fore-quarter which was systematically richer than that from the hind-quarter, whilst another yielded richer milk from the hind than from the fore-quarter; the third cow showed no such characteristic differences. Generally then the conclusion must be drawn that characteristic differences both of yield and of quality of milk from the fore and hind-quarters of the udder of cows may commonly occur. Taken in conjunction with the uniformity of composition of the whole milk of individual cows, this would seem to indicate that the quality of the milk is a function of the tissue of that region of the cow's udder in which it is produced and that though the opposite sides are symmetrical in this respect, the udder is in other directions no more uniform in function than it is in shape.

This conclusion is in accordance with those drawn by Ingle;* though he found that in respect of the percentage of solids-not-fat, the milk from corresponding quarters of opposite sides of the udder differed very considerably and erratically.

* *Highland and Agric. Soc. Trans.* 1903, XV, 135.

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